Section G (Mechanics 1)

Answer all the questions.

Answer these questions in a separate answer book, showing clearly the section chosen.

Where appropriate, candidates should take the magnitude of the acceleration due to gravity as 9.8 m s$^{-2}$.

G1. A motorcyclist moves from rest along a straight, horizontal road, with acceleration $2t$ m s$^{-2}$, where $t$ is the unit vector in the direction of motion, and $t$ is the time in seconds from the start of the motion.

Calculate the distance travelled by the motorcyclist in the time taken for the speed to increase from 1 m s$^{-1}$ to 9 m s$^{-1}$.

G2. A car of mass $m$ kilograms is travelling in a straight line along a horizontal road at constant speed $U$ metres per second when the driver applies the brakes. The brakes cause a constant retarding force $R$ newtons which brings the car to rest in a distance of $D$ metres.

Find an expression for the stopping distance $D$ in terms of $m$, $U$ and $R$.

Comment on how the stopping distance depends on the mass of the car.

G3. The diagram below shows a car of mass $m$ kilograms which is held in equilibrium on the back of a stationary lorry by means of a light inextensible chain $AB$ which runs parallel to the sloping surface. This surface is inclined at an angle of $\theta$ to the horizontal and the coefficient of friction between the car and the surface is $\mu$.

![Diagram of car on lorry](image)

When $\theta = 30^\circ$ the tension required in the chain $AB$ to prevent the car slipping down the slope is $T$ newtons. When $\theta$ is increased to $45^\circ$ the tension required in $AB$ becomes $2T$ newtons.

(a) When $\theta = 30^\circ$ show that

$$T = \frac{1}{2}(1 - \sqrt{3}\mu)mg,$$

where $g$ m s$^{-2}$ is the magnitude of the acceleration due to gravity.

(b) Find an expression for $T$ in terms of $m$, $\mu$, and $g$ when $\theta = 45^\circ$.

(c) Find the value of $\mu$.

[Turn over for Questions G4 and G5 on Page twenty]

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G4. A light aircraft is travelling due north at a constant altitude of 1 km with constant speed $100\sqrt{2}$ km/h. At 1 pm a helicopter is $50\sqrt{2}$ km due west of the aircraft, and travelling in a north easterly direction at a constant altitude of 2 km with constant speed 100 km/h.

Taking the position of the aircraft at 1 pm as the origin, and defining an appropriate set of unit vectors, find the position of the helicopter relative to the aircraft in terms of time $t$ hours after 1 pm.

G5. An artillery shell is launched from the point $A$, which is $H$ metres vertically above the point $O$ on level ground, as shown below. The shell is projected at an angle $\alpha$ above the horizontal, where $0 < \alpha < \frac{\pi}{2}$, with speed $\sqrt{2gH}$ metres per second, where $g$ m s$^{-2}$ is the magnitude of the acceleration due to gravity.

\[ y = H + x\tan\alpha - \frac{(1 + \tan^2\alpha)}{4H}x^2. \]

[Note that $\frac{1}{\cos^2\alpha} = 1 + \tan^2\alpha$.]

(a) Show that, referred to the axes shown, the equation of the trajectory of the shell is

(b) The shell lands at the point $B$ on the ground, a horizontal distance of $2H$ metres from $O$, as shown.

Show that $\tan\alpha = 2$.

(c) Show further that the maximum height above the ground attained by the shell is $\frac{3}{4}H$ metres.

[END OF SECTION G]

[END OF QUESTION PAPER]